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ABSTRACT

Previous research has shown that expert physicians' diagnostic performance improves when contextual information about a patient is available, while the performance of novices is not influenced by this source of information. These results are explained by supposing that experts' knowledge is organized in illness-scripts. This study examined this proposition. Subjects were 23 fourth-year and 22 sixth-year medical students, 23 interns in their second years of internship, and 22 family physicians. Students were from the Netherlands, and physicians were from the Netherlands or Belgium. Stimulus material consisted of 20 names of diseases. Subjects were asked to describe prototypical patients or to describe the clinical pictures involved in the diseases. Results are in agreement with the theory that with increasing expertise, knowledge structures qualitatively change toward more mature illness scripts. With increasing level of expertise, the proportion of patient characteristics in the subjects' descriptions of diseases increases, while the proportion of biomedical knowledge increases. Furthermore, experts tend to activate patient information without regard to probing condition, while intermediates activate this information only if explicitly asked. A 14-item list of references and two appendices with a list of the illnesses and examples of protocols subjects described are included. (SLD)

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The Relationship Between Medical Expertise and the Development of Illness-Scripts

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Abstract

Previous research has shown that expert physicians' diagnostic performance improves when contextual information about a patient is available, whereas novices' performance is not influenced by this source of information. These results were explained by supposing that experts' knowledge is organized in illness-scripts. The present study confirms this proposition. It is shown that with increasing level of expertise, the proportion of patient characteristics in the subjects' descriptions of diseases increases, while the proportion of biomedical knowledge decreases. Furthermore, experts tend to activate patient information irrespective of probeing condition, while intermediates activate this information only if explicitly asked to.

INTRODUCTION

During the years 1960-1980, research on human problem solving was heavily influenced by the work of Newell and Simon (Newell, Shaw, & Simon, 1959; Newell & Simon, 1972). The development of expertise in problem solving was seen as a consequence of the development of a repertory of general purpose problem solving strategies (i.e., means-ends analysis) which was considered to be useful irrespective of the specific nature of the domain it would be applied to. Though specific knowledge of a particular domain was not rejected as entirely unimportant or useless, it was de-emphasized. By choosing research topics relatively devoid of specific content knowledge, such as simple arithmetic problems or logic proofs, the importance of general problem solving strategies could easily be demonstrated. A salient aspect of these domains is that it is possible to become an expert on the tasks studied within at most a few hours.

Some attempts have been made to incorporate general problem solving methods in areas that require more knowledge of specific content. For example, Cutler (1979) describes 19 different problem solving methods to be used by physicians, though a substantial number of these are actually not problem solving methods at all, at least not from a psychological point of view (e.g., Venn diagrams or computers). However, in knowledge-rich domains like medicine, the general problem solving approach has run into trouble. Even an extensive repertory of general problem solving methods is in itself not sufficient to exhibit expert behavior in fields like medicine. Intuitively, it seems evident that training on these strategies cannot replace the estimated 21.800 hours of education and practice (Boshuizen, 1989) that are required to make a beginning medical student an expert physician. Moreover, empirical research (e.g., Elstein, Shulman & Sprafka, 1978) failed to find evidence for the supposition that general problem solving methods play an important role in medical diagnosis.

Why then are experienced physicians better diagnosticians than novice physicians? Research by Barrows, Norman, Neufeld, & Feightner (1982) and Elstein et al. (1978) has shown that critical differences between novices and experts become manifest in the quality of the early diagnostic hypotheses. Even in the first minutes of a consultation, experts produce more accurate diagnostic hypotheses than novices. Apparently, it is not better use of general problem solving methods, but changes in the way their knowledge is structured that is responsible for the superior diagnostic performance of expert physicians.

The finding that experienced physicians outperform medical students and clerks from the very beginning of the medical consultation, suggests that the former group exploits the information available at the initial stages of the clinical encounter to a larger extent than the latter group. Usually, the most important source of information available in the beginning of the clinical encounter is the context of the patient. Thus, it might be concluded that experienced physicians are more sensitive to contextual information about a patient (e.g., information about the patient's age, sex, medical history, occupation, current therapy, risk behavior, heriditary predispositons) than inexperienced physicians. Indeed, as Hobus, Schmidt, Boshuizen, & Patel (1987) and Hobus, Hofstra, Boshuizen, & Schmidt (1988) have shown, medical experts

actually use this kind of information to generate more accurate diagnostic hypotheses, whereas the performance of inexperienced physicians does not improve at all when contextual information is available.

These results are rather puzzling, because even the clinical textbooks students are supposed to study in the pre-clinical phase provide ample information on incidence rates, patient characteristics and associated risk factors. Probably, expert physicians have knowledge about the significance of this contextual information integrated into their knowledge structures and are thus able to take advantage from it in their diagnostic performance. According to Schmidt, Boshuizen, & Hobus (1988) and to Schmidt, Norman, & Boshuizen (1990), medical experts have their clinical knowledge represented in illness-scripts. In the original approach by Feltovich & Barrows (1984), an illness-script was seen as a loosely connected format, structured together by means of biomedical knowledge. In a more recent view (Schmidt, Norman, & Boshuizen 1990), an illness-script is conceptualized more as a narrative structure that can be activated as an integrated whole in a practical situation. In an illness-script, the important clinical knowledge about a disease is contained in three components: The "Enabling Conditions" (the pertinent patient-characteristics and contextual information), the "Fault" (classes of malfunction in the human body) and the "Consequences" (the specific signs, symptoms and complaints resulting from this Fault).

The theory states that illness-scripts change during development of medical expertise. During the preclinical phase, detailed biomedical knowledge is gathered and an elaborate network of factual medical knowledge is constructed. Experience in practical settings, for example in the clerkship stage, triggers the formation of higher-order concepts by a process called "encapsulation" (Schmidt & Boshuizen, 1992, in press). Simultaneously, the role of overt biomedical knowledge in clinical reasoning decreases . Experience in a practical setting on the other hand results in the gradual differentiation and integration of knowledge about the Enabling Conditions into the script-structure, as Hobus et al. (1987) have shown. Knowledge about Consequences also increases, but at a different time scale: The illness-scripts of advanced students and those who recently graduated from medical school are already relatively well-developed with respect to the Consequences-component, but they lack critical knowledge concerning the Enabling Conditions-component (Hobus, Boshuizen, & Schmidt, 1989). Probably, it takes more practical experience to integrate Enabling Conditions into an illness-script structure than to add Consequences to it. Anyhow, the acquisition of a knowledge base of sophisticated and full-fledged illness-scripts requires several years of medical study, supplemented by a great number of patient-encounters in practical settings.

The present study was designed to corroborate some of these earlier findings and to explore the development of illness-scripts in greater detail. If the illness-script theory is an appropriate approach, then the descriptions of diseases by subjects at different levels of expertise will reflect a development towards integrated knowledge structures that gradually become enriched with Enabling Conditions. Hence, if requested to tell something about a disease, expert physicians will tend to activate the illness-script of that particular disease and will generate relatively many Enabling Conditions and little biomedical knowledge (i.e., Fault-

elements). Preclinical students, on the other hand, will give descriptions more in accordance with medical textbook structures and thus will be more apt to produce biomedical knowledge, while they will provide little information on Enabling Conditions. An intermediate position will be taken by advanced students and interns: As their illness-scripts are of a rather sketchy nature and consist of loosely connected elements, the way they describe diseases will be susceptible to differences in the probes that are used to activate their knowledge. Hence, when explicitly asked to describe a patient with a certain disease, these intermediates will come up with more Enabling Conditions than when asked to describe the clinical picture this disease produces, whereas neither the responses of expert physicians nor those of preclinical students will be much affected by differences in eliciting cues. Regardless of specific type of probe, experts will almost always provide some information on Enabling Conditions, because this forms part and parcel of their activated illness scripts, while preclinical students will give little information in this category anyhow: They still lack much of the relevant knowledge.

METHOD

Subjects. Subjects were 23 fourth-year students, 22 sixth-year students, 23 interns in the second year of their internship and 22 family physicians. The fourth-year students had no or negligible experience in a practical clinical setting, while the sixth-year students, interns and physicians had on the average respectively 2 years, 5.5 years and 13.9 years experience in such settings. All subjects were either studying at the Limburg University at Maastricht (the Netherlands) or practicing in the neighbourhood. Four physicians were working in a practice in Belgium.

Material. The stimulus material consisted of 20 names of diseases, the same diseases as were used in the study of Hobus, Boshuizen, & Schmidt (1990). Earlier experiments had shown that contextual information could play a facilitative role in the activation of accurate diagnostic hypotheses for these diseases (Hobus et al., 1987). Furthermore, the diseases selected displayed substantial variance as far as seriousness of the illness, afflicted organ system and frequency of occurrence in real-life situations are concerned. The names of the diseases are depicted in Appendix I. Two diseases (A and B) were used for practicing purposes only. Disease 9 (secondary enuresis nocturna) was excluded from the analysis because there was considerable confusion among the subjects with respect to the nature of this "disease".

Procedure. Subjects were randomly assigned to one of the two conditions. In the "prototype"-condition, subjects were asked to describe prototypical patients for each of the 20 diseases, in the "clinical picture"-condition they were requested to describe the clinical pictures involved in each of the 20 diseases. The rationale behind these two probes was that an instruction to describe a prototypical[1] patient would cue subjects towards Enabling Conditions, while an instruction to describe a clinical picture would probably cue towards Consequences. Especially subjects at intermediate levels of expertise were expected to be influenced by the specific type of probe. In Appendix 2 some examples are shown of subjects' descriptions. Subjects were tested individually. All narratives were audiotape recorded; there were no time

constraints on the duration of either the entire session or the individual disease-descriptions. The modal duration of a session was 20-30 minutes. At the end of the session subjects were asked how many patients they themselves had encountered with each of the 20 diseases, in order to investigate a possible relation between number of patient encounters and the information given about the diseases.

Analysis. Verbatim protocols were derived from the audiotape recordings. Protocol-statements were classified into five categories: Enabling Conditions, Fault, Consequences, Treatment & Course and a rest-category. An expert physician, whom had experience with the illness-script categories, was consulted in order to establish a sound basis for the classification. Generally, not many difficulties were encountered during categorization. If in doubt, statements were recorded in the Fault category, so as to avoid biasing the results in the expected direction. It should be emphasized that all statements were classified into the illness-script categories, whether or not they could be considered true or false for the disease at hand from a medical point of view.

As "free production" tasks usually result in large inter-individual differences in total number of statements, analyses were performed both on the actual number of statements in each category, and on the respective proportions. Number and proportion of statements in each of the illness-script categories were analyzed by means of a 4 (levels of expertise) by 2 (probes) analysis of variance.

RESULTS AND DISCUSSION

Analysis of variance revealed a significant main effect of level of expertise $F(3,81) = 9.661$, $p < .0001$ on the relative contribution of Enabling Conditions to the descriptions offered by the subjects (Figure 1). Generally, a higher level of expertise is associated with a higher proportion of Enabling Conditions in the descriptions. There was also a significant main effect of probe $F(1,81) = 36.88$, $p < .0001$ on the proportion of Enabling Conditions. The instruction to describe a prototypical patient generally yielded relatively more Enabling Conditions than the instruction to describe the clinical picture of a disease. As far as the absolute number of Enabling Conditions is concerned, the results are essentially the same: $F(3,81)=8.119$, $p < 0001$, for level of expertise and $F(1,81)=28.154$, $p < .0001$, for probe.

Figure 1 also shows a significant interaction between level of expertise and probe on the proportion of Enabling Conditions ($F(3,81) = 3.77$, $p < .02$). It appears that neither students nor family physicians are sensitive to type of probe: The relative contribution of Enabling Conditions is in both conditions rather small in students and rather high in family physicians.

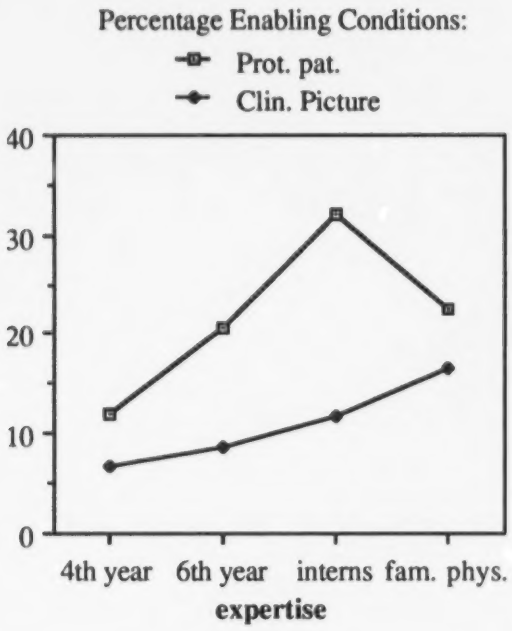

Figure 1. Relative contribution of Enabling Conditions in subjects' descriptions

However, subjects at the two intermediate levels of expertise (i.c., sixth-years students and interns) are inclined to give a higher percentage of Enabling Conditions in their descriptions when asked to describe a prototypical patient than when asked to describe the clinicical picture. Thus, subjects at intermediate levels of expertise are more sensitive to the differences in probe than either fourth-year students or family physicians.

Probably due to large within-group variances, the interaction between level of expertise and probe on the absolute number of Enabling Conditions is only borderline significant: $F(3,81)=2.617$, $p < .06$.

As yet, we have no explanation for the unexpected peak in the proportion of Enabling Conditions in the "prototypical patient" protocols of the interns. Though separately computed contrasts revealed no significant differences between sixth-year students, interns and family physicians, it is nevertheless possible that the phenomenon somehow reflects the intermediate effect described in the literature (Schmidt, Boshuizen & Hobus, 1988; Schmidt, Norman, & Boshuizen, 1990).

As predicted, the proportion of Fault-elements diminished with increasing levels of expertise ($F(3,81) = 15.70$, $p < .0001$). The same result holds for the number of Fault-elements mentioned. Figure 2 shows the results. While biomedical and pathophysiological information forms a substantial part of the stories told by fourth-year students, interns and family physicians provide hardly any information of this kind. Neither a significant main effect of probe, nor an interaction between level of expertise and type of probe was found. These results suggest that the decrease of Fault-related statements in verbal descriptions is a general feature of increasing expertise.

As far as the number or the proportion of Consequences is concerned, the results are difficult to interpret. Differences in proportion of Consequences mentioned between subjects on each of the four levels of medical experience are surprisingly small: they vary between 64.7% for interns and 66.9% for fourth-year students and sixth-year students, with the family physicians

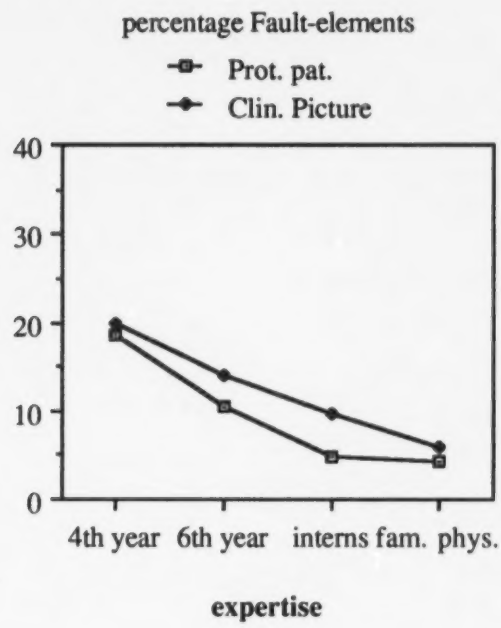

Figure 2. Relative contribution of Fault-elements in subjects' descriptions

falling in-between. Thus, about two-thirds of all statements fall in this category. However, the preceding conclusion that subjects at the intermediate levels of expertise are more sensitive to type of probe than either students or experienced physicians also seems to apply here. The results are depicted in Figure 3. The main effect of type of probe on the proportion of Consequences in the descriptions was significant ($F(1,81)=5.473$, $p < .03$). The interaction between level of expertise and type of probe was borderline significant ($F(3,81)=2.552$, $p < .07$). These results suggest that subjects who are requested to describe the clinical picture of a disease are more apt to volunteer Consequences than subjects who are probed to describe a prototypical patient with that particular disease, and also that intermediates (i.e., sixth-year students and interns) are more sensitive this kind of probe-differences. That these results are not simply an artifact of the consequence of using percentages, (i.e., that their sum always equals 100) is indicated by the finding that the pattern of actual number of Consequences in the descriptions shows the same tendency.

Analysis of the number and proportion of statements in the Therapy & Course category showed no significant main effect of level of expertise or type of probe, nor a significant interaction. On the avarage, only 6.5% of all responses fell into this category, so significant differences could hardly expected to be found, all the more since large within-group, (and even within-subjects, for particular diseases) differences were found in number or proportion of responses in this category: if subjects supplied information on course and/or therapy of a particular disease, often two or more statements in this category were mentioned (see, for example, the fourth protocol in Appendix 2).

Generally, the present study supports the hypothesis that the integration of Enabling Conditions in illness-script structures occurs as a consequence of experiences with patients in a practical setting: In the sixth-year students group, a (Pearson-)correlation of .53 ($p < .02$) was found between frequency of patient-encounters reported and the proportion of Enabling

Conditions mentioned, while this correlation dropped to .32 in the interns group and .03 in the family physicians group; both latter values do not differ significantly from zero. Interestingly, the correlation between frequency of patient-encounters and proportion of Enabling Conditions within the group of clerks can not be attributed solely to experience with a few rather frequently occurring diseases: no significant differences were found between proportion or number of Enabling Conditions mentioned on frequently occurring diseases (e.g., nervous gastritis, stomatitis aftosa, perforated otitis media) and proportion or number of Enabling Condtions mentioned on rarely occurring diaseases (e.g., rupturing aneurysm of the aortic artery, carcinoma of the head of the pancreas, epidural hematoma). This suggests that the integration of Enabling Conditions in illness-scripts structures is a general feature of developing medical expertise and not restricted to practical experience with specific diseases.

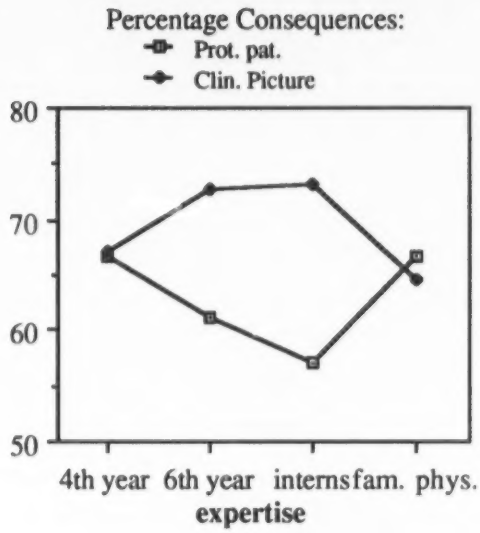

Figure 3. Relative contribution of Consequences in subjects' descriptions

In conclusion, these results are in agreement with the theory that with increasing expertise knowledge structures qualitatively change towards more mature illness scripts. Fourth-year students' illness-scripts are very incomplete; they lack much of the relevant knowledge concerning Enabling Conditions. Even if explicitly asked to describe a prototypical patient, they come up with a very limited amount of contextual information. Intermediates, on the other hand, have this kind of knowledge at their disposal, but it is not yet integrated in illness-script structures, and as a consequence not yet universally available. Finally, experienced family physicians' disease knowledge is organized in stable, full-fledged illness scripts. They tend to activate Enabling Conditions, even if probed in a different direction. These results indicate that though knowledge about Enabling Conditions may be gathered in the earlier stages of the development of medical expertise, the process of integrating this knowledge into illness-script structures extends well beyond the intermediate stages. In the meantime, information about Fault-related aspects is "wedged away" to the background, probably as a result of "encapsulation" of this knowledge (Boshuizen & Schmidt, 1992, in press) .

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APPENDIX 1

Names of the diseases used in the study:

A. Metastatic sigmoid cancer (metastases in the lungs)
B. Dyspepsia on a nervous basis (also called: nervous gastritis)
01. Aneurysm of the aortic artery (threatening rupture)
02. Urosepsis
03. Dermatitis peri-oralis
04. Vaginal Candidiosis
05. Perforated otitis media
06. Kidney stones (colic)
07. Carcinoma of the head of the pancreas
08. Stomatitis aftosa (multiple small ulcera in the mouth)
09. Secondary enuresis nocturna[2]
10. Digitalis Intoxication
11. Epidural hematoma
12. Nervous abdominal pain
13. Pediculosis pubis
14. Herpes zoster
15. Meningitis or encephalitis as a complication of mumps
16. Hepatitis A
17. Monilia of the mouth
18. Pre-infarct syndrome

APPENDIX 2

Examples of protocols: (The target disease was "herpes zoster")

"enabling conditions centered":
eh, also an elderly man or woman, an elderly man or woman, also in a somewhat-what bad shape, a bit emaciated, perhaps; probably, but not necessarily, known with underlying afflictions,- eh- who gets a rash, and pain, in a certain segment...

"fault centered":
-it's the chicken-pox virus, you've had chicken-pox in your youth, and the virus settles down in your nerves, -and you get vesicles on your skin, and these are very contagious, because the fluid contains the virus, and you'll never get rid of it-; and it can cause an infection of the eyes, and that might be very dangerous...

"consequences centered":
-pain, unilateral, in the shape of a belt, and it coincides with a skin nerve, and eh- not always in the shape of a belt-, it might be, but not when it's on your head, or on your legs-; anyway, it coincides with a skin nerve, -redness, a swelling, an elevated swelling, with vesicles, and eh- hypersensitivity, and often a general feeling of weak health- a classical picture-

-"clinical course / therapy centered":
-in the elderly often a problem, because they visit the physician in a stage when it's already too late to treat it properly- nowadays with Zovirax-pills; eh- very nasty disease, many problems with so-called post-herpetical pains, these may continue to trouble the patient for years and are very difficult to combat; eh- in the beginning stages often difficult to diagnose, -in case of vague, unexplainable pains I'm always on guard and ask them to return the next day

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[1] In order to avoid the possibility that family physicians would come up with a very specific patient (e.g., a case recently encountered) instead of a more general, script-like description, it was emphasized to give the description of a prototypical patient.

[2] Omitted from the analysis